ENGINEERING PEDAGOGY SCIENCE AS THE CONTEMPORARY BASIS FOR EFFECTIVE TEACHING OF SCIENCE, TECHNOLOGY AND ENGINEERING

Tiia Rüütmann
Tallinn University of Technology, Estonia
E-mail: tiia.ruutmann@ttu.ee

Abstract

This study is introducing the basic principles of Engineering Pedagogy Science for effective design, teaching and learning of science, technology and engineering. The basic didactical models are introduced for contemporary design of effective teaching and learning. A quadruple instruction model of Engineering Pedagogy Science is proposed, integrating the principles of Behaviourism, Cognitivism, Social Constructivism and Humanism on the basis of didactic model of Engineering Pedagogy Science.
Keywords: *didactical model, effective teaching of STE, engineering pedagogy, educational design, quadruple instruction model*.

Introduction

Engineering Pedagogy Science is a young interdisciplinary branch of pedagogical science that gives an overview of specific problems that arise in teaching STE (Science, Technology, and Engineering) subjects and helps to acquire necessary tools and skills to teach these subjects efficiently and competently. Scientific ideas of Engineering Pedagogy are primarily targeted for STE practitioners: engineers, doctoral students, knowledge workers, teachers and trainers who teach at upper secondary schools, vocational training institutions, and universities. The basic knowledge of Engineering Pedagogy Science, including STE didactics, enables to design teaching effectively, flexibly and taking account of the learning situation, so that poor teaching becomes better and good teaching - excellent, thus supporting effectual learning with deep understanding.

Psycho-Didactics and Engineering Pedagogy Science

Psycho-didactics is a multidisciplinary new field that combines the principles of psychology and didactics and creates the basis for effective teaching ensuring individualized education. The scientific ideas of psycho-didactics are one of the most important foundations of Engineering Pedagogy and STE didactics. The aim of psycho-didactics is to support the emotional, intellectual and ethical development of learners' personality and to develop the importance of values in the process of learning. Teaching critical thinking and supporting metacognition are also of great importance.

If the main issues of didactics were to define "*what to teach?"*, "*how to teach*?", and "*why to teach?"* psychology adds "*who teaches*?", "*who is taught*?" and "*where is it taught*?". Expanding the main issues of didactics through the definition of supportive learning environment and the psychoanalysis of students and teacher, it should be emphasized that both - the learner's individual differences and preliminary knowledge, and the professionalism and competency of a teacher are of great importance in activating the process of cognitive learning in teaching and learning STE.

From Didactic Triangle to Didactic Pentagram

Didactic models ensure the design and analysis of effective teaching, and reflection on the educational process with the aim of improving teaching and learning, and perfecting the scholarship of teaching and learning (SoTL). For effective teaching STE a didactic pentagram of Engineering Pedagogy Science has been designed by the author of the present article taking account of the ideas of Uljens (1997), see Figure 1.

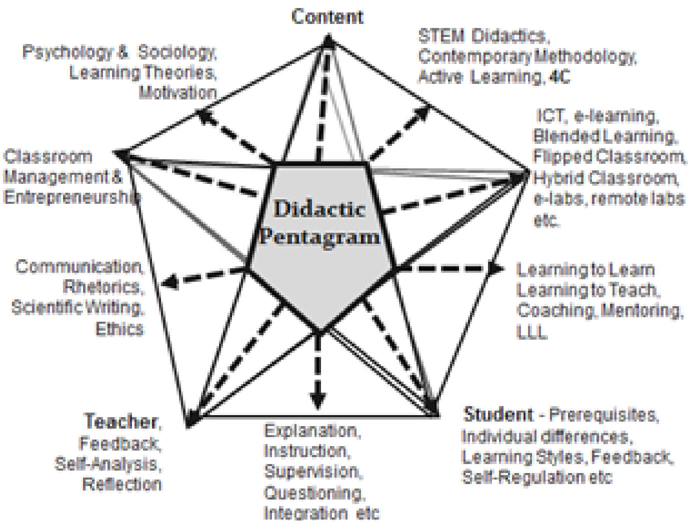

Figure 1. Didactic pentagram of engineering pedagogy science.

The didactic pentagram of Engineering Pedagogy Science is designed of different supportive didactic triangles placed on top of each other, built on the classic didactic triangle (teacher-students-content and continuous feedback between them). All the lines, arrows and pentagram sides relate on different aspects of effective teaching and learning STE.

The Didactic Model of Engineering Pedagogy Science

The didactic model of Engineering Pedagogy Science that has been developed by the author of the present article taking account of the principles of the Klagenfurt School of Engineering Pedagogy (Melezinek 1999), is presented in Figure 2 following the didactic questions below (Rüütmann 2019):

- *Why we teach*? – Is there any need for this course? Set clear and precise goals and relevant learning outcomes. By achieving our teaching goals, we create conditions and opportunities for our students to achieve their learning outcomes. For goal setting use didactic models (e.g. Bloom's taxonomy (Anderson et al. 2001), Feisel-Schmitz's taxonomy (Crawley et al. 2014), Hmelo-Silver's PBL taxonomy (Hmelo-Silver 2004) etc.) and take account of three types of learning: cognitive, psychomotor and value domains. (Crawley et al. 2014);
- *Whom we teach?* – Analyse your target group, take account of their individual differences, learning styles, prior knowledge and how they learn (psycho-structure). Check whether the goals you have set are appropriate for your students' prior knowledge;
- *What we teach?* – Select only the most important content taking account of the goals and students' prior knowledge, create logical structure. The time as a resource should be taken account of in order to create a balance between the scope and complexity of the content selected for learning. Align the content with the goals and students' prior knowledge, compile assignments and e-learning materials, simulations, videos etc.;
- *With what and where we teach?* – Select relevant facilities and technology (socio-structure); create a supportive, positive learning environment. Select suitable new and classical teaching technology, media, laboratory equipment, online platform for e-learning etc. Align teaching technology and facilities with the content, students' prior knowledge and learning outcomes;
- *How we teach?* – Select and analyse suitable teaching models, methods, strategies, ways of communication, set the ratio between individual and group work etc. Analyse if the selected teaching models, methods and strategies are relevant to the teaching technology, content, students' prior knowledge – do they support critical thinking and reaching the learning outcomes;
- *How we assess and give feedback?* – Select relevant assessment and feedback methods that are suitable for the learning outcomes, content, take account of specifics of selected teaching methodology and teaching technology and analyse students' critical thinking. How to ask and give feedback with the aim of supporting and improving teaching and learning?
- *How to improve the process of teaching and learning?* Analyse and reflect on the process of teaching and learning. Are the goals and learning outcomes, students' prerequisites, selected content, technology, and assessment methods effective and efficient? Ask students and colleagues for feedback. If necessary, make changes to improve the quality of teaching and learning. Upgrade your teaching skills and teach students how to learn with deep understanding.

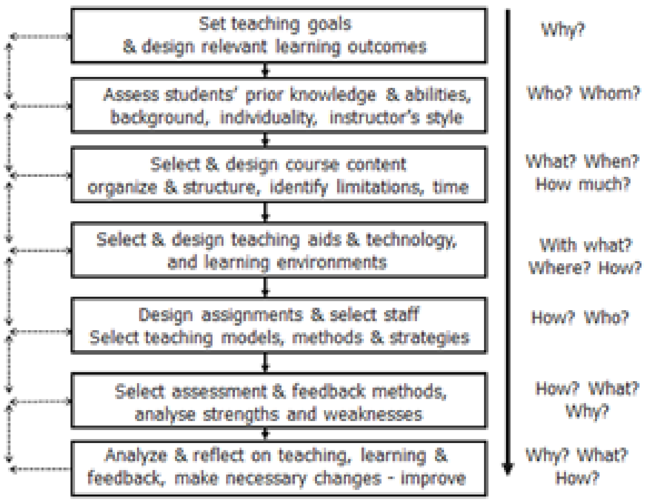

Figure 2. The didactic model of engineering pedagogy science.

Thus effective teaching of STE is influenced by a number of variables:
- Instructional objectives (O);
- Students' psycho-structure, prior knowledge and individual differences (P);
- Course content (C);
- Teaching technology and socio-structure (T);
- Teaching models and methodology (M);
- Assessment and feedback methods (A);
- Reflection and analysis of teaching and learning (R).

In Engineering Pedagogy Science teaching method is a function of different influential factors: M = f (O, P, C, T, A, R). If one of the variables will change, the methodology has to be changed. (Melezinek 1999).

There are always three types of learning: cognitive (knowledge), psychomotor (skills) and affective (values) being integrated in teaching STE.

Design of a Quadruple Instruction Model of Engineering Pedagogy Science

This study proposes a comprehensive quadruple instructional model of Engineering Pedagogy that has been designed on the basis of the didactic model of Engineering Pedagogy Science (Figure 2) and integration of four basic learning theories: Behaviourism, Cognitivism, Social Constructivism and Humanism (see Figure 3).

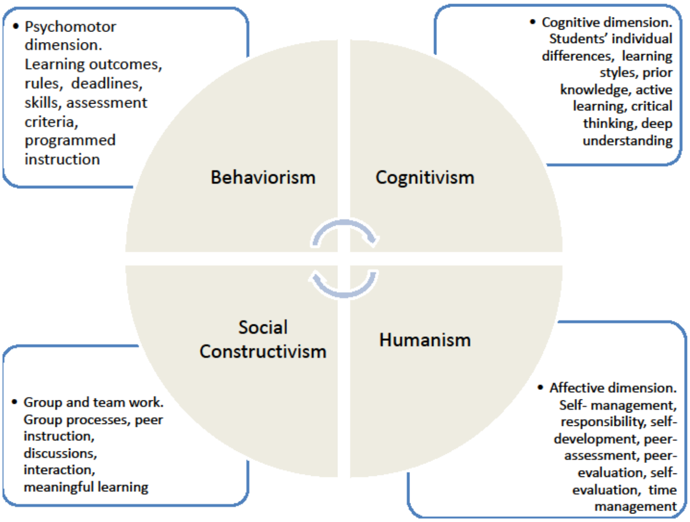

Figure 3. Integration of four basic learning theories.

Behaviourism supports the psychomotor dimension (acquisition of skills) in teaching STE. Behaviourism mainly contributes for the students' level - beginners. Behaviourism contributes for design of learning goals and learning outcomes, develops requirements, rules (including safety regulations), deadlines, and verifiability of results, takes account of differentiation, teaches to solve STEM problems, supports practicing, repeating, and implementation. Assessment is carried out according to assessment criteria with tests and exams. Teaching methodology of Behaviourism is: lectures, laboratory works, demonstrations, practicing, questioning etc. Teaching model is deductive teaching. Role of a teacher is manager; role of a student is to act according to the plan delivered by the manager.

Cognitivism supports the cognitive dimension (acquisition of knowledge). Constructivism is one construct of cognitivism. Cognitivism mainly contributes for the level of intermediate students. Cognitivism takes account of students' individual differences, learning styles, prior knowledge, and activity, integration, learning with comprehension, critical thinking, and chain of perception-knowledge-thinking. Cognitivism contributes for teaching methodology and strategies like: active learning, interactive lessons, concept maps, visualisation, integration, PBL, studio learning etc. Multiple choice tests are used. Teaching model is inductive teaching. Role of a teacher is supervisor, role of a student - explorer.

Social Constructivism supports cooperation and collaboration, and contributes with group and team work, peer instruction, imitation, analysis of group processes, discussions and interaction, knowledge exchange and experiential learning, meaningful learning with deep understanding and comprehension, supervision. Role of a teacher is facilitator, role of a student – team member. The process of a team work is assessed by self- and peer-assessment, feedback is used.

Humanism supports affective dimension (values and attitudes) contributing mainly for the advanced level of students. Humanism contributes with self-management,

responsibility, self-development, peer-assessment, peer-evaluation, peer-instruction, time-management, and self-regulation, discussions. Assessment is carried out on the basis of a scale or check-list and on the basis of feedback. Role of a teacher is mentor, role of a student – designer. Mentoring and coaching is widely used.

In Figure 4 a comprehensive quadruple instructional model of Engineering Pedagogy is presented.

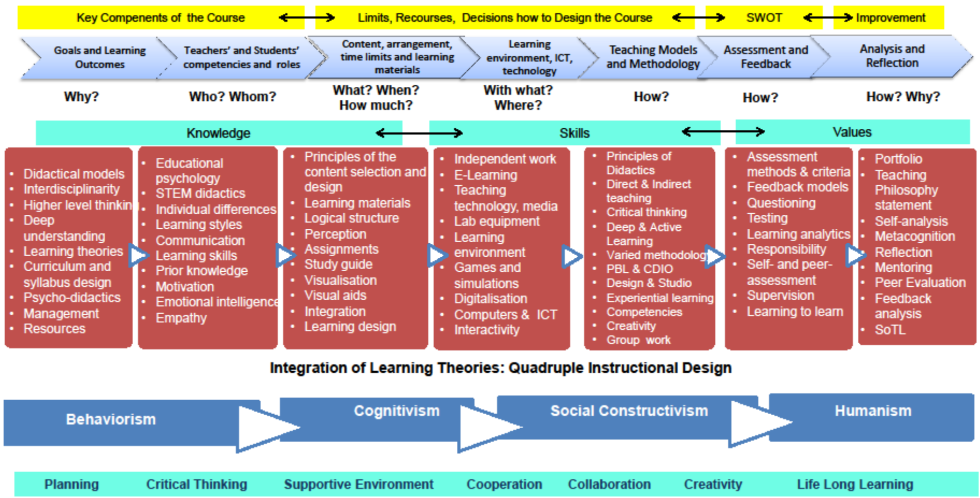

Figure 4. A quadruple instruction model of engineering pedagogy science.

In the process of development of a quadruple instructional model of Engineering Pedagogy Science, the Didactic Model of Engineering Pedagogy Science has been integrated with the principles of four basic learning theories. The presented model is an effective tool for a productive instructional design in the field of STE. The quadruple instructional model of Engineering Pedagogy Science has been implemented in the curriculum and instructional design of the Technical Teacher Master programme at Estonian Centre for Engineering Pedagogy. Feedback from the students, faculty and stakeholders has been positive.

Conclusions

In the process of planning STE teaching, the fact that effective teaching is a unique art should be considered. The actual process of learning develops in a real world environment. Thus, depending on learning goals and outcomes, students' prior knowledge and individual differences, learning skills, motivation, course content, methodology, technology effective lesson could be developed according to the real learning situation. Therefore, knowledge of STE didactics helps teachers and faculty to make scientifically informed decisions and relevant changes to support students' learning with deep understanding. The proposed quadruple instruction model of Engineering Pedagogy Science enables the design of an effective STE teaching.

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